NEAR REAL-TIME RESPONSE MATRIX CALIBRATION FOR 10 Hz GOFB*

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Abstract

The 10 Hz global orbit feedback (GOFB), for damping the trajectory perturbation (∼10 Hz) due to the vibrations of the triplet quadrupoles, is operational. The correction algorithm uses transfer functions between the beam position monitors and correctors obtained from the online optics model and a correction algorithm based on singular value decomposition (SVD). Recently the calibration of the transfer functions was measured using beam position measurements acquired while modulating dedicated correctors. In this report, the feedback results with model matrix and measured matrix are compared.

INTRODUCTION

In RHIC, 10 Hz horizontal beam perturbations in both rings are suspected to be caused by vibrations of the final focusing quadrupoles (triplets) [1, 2]. The 10 Hz GOFB system [3], consists of 36 BPMs, corresponding to 2 per triplet in each of the 12 triplet locations and two in each of the 6 arcs, and 1 dipole corrector at each triplet location for a total of 12 correctors, has been operational since Run-11. The feedback worked at injection and store for all physics runs so far. This system reduces the 10 Hz oscillation amplitude at IR BPMs by a factor of more than 3 both at injection and store. The damping effect from 10 Hz feedback is shown in Fig. 1 for 100 GeV proton at store in Run-12.

ORM MEASUREMENT

Direct measurement of the transfer functions eliminates possible errors in the BPM and corrector calibrations or in the optical model. Orbit response matrix (ORM) measurements were performed in both accelerators during these calibration measurements. The correctors were driven sequentially at 12 Hz while the BPM values were recorded at a sampling rate of 1 kHz.

Measurement Data

An example of BPM data during the excitation of correctors is shown in Fig. 2. The oscillation amplitude of beam positions is proportional to the oscillation amplitude of corrector strength and the response of that BPM to the corresponding corrector. The corresponding corrector angles are shown in Fig. 3, showing the envelope of the applied 12 Hz excitations.

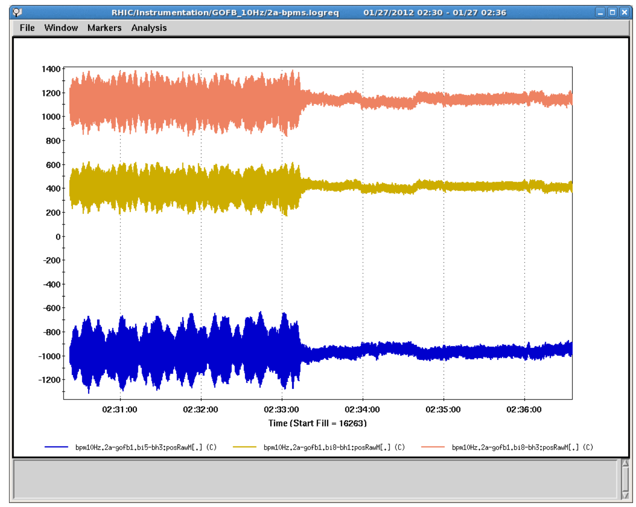

Figure 1: Beam positions recorded at IR BPMs at 1 kHz rate before and after 10 Hz feedback was engaged.

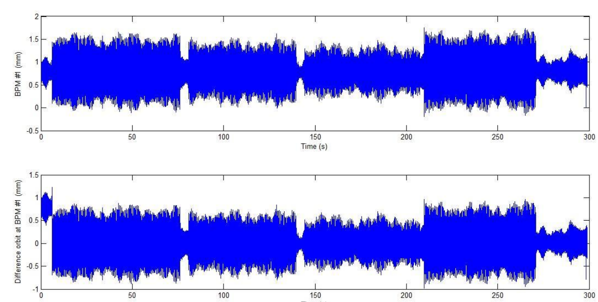

Figure 2: Beam positions recorded at one IR BPMs during the process of exciting 4 correctors, the top plot is the original beam position oscillations, the bottom plot is the centered beam position oscillations.

ORM FROM MEASUREMENT

Three different methods for generating the response matrix from the experimental data were evaluated [4]. All methods aim to extract the slope $dx/d\theta$ due to the applied excitation while minimizing contributions due to other sources of perturbation to the beam trajectory such as from the triplet vibrations.

The first and standard method for calculating the response matrix R is to create correlation plots between the BPMs and correctors, perform linear fitting, extract slopes which correspond to the elements of the orbit response matrix. The other two equivalent methods require determi-

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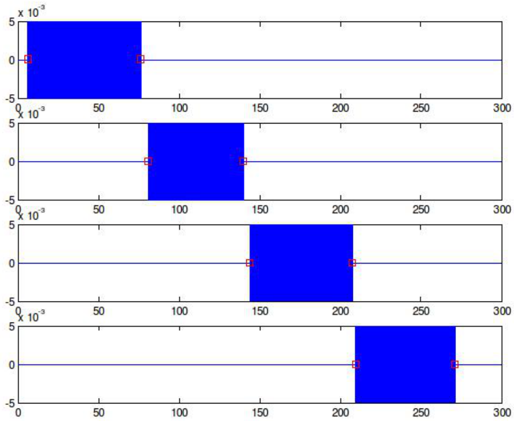

Figure 3: Modulation of corrector strength during the measurement.

nation of the amplitudes of the beam displacement at the applied excitation frequency. The ratio of this amplitude to corrector strength amplitude gives the matrix elements. Extracting the beam response was evaluated in both the time and frequency domains using curve fitting and fast Fourier transforms (FFT) respectively. The sign of each matrix element can be derived by inspection of the relative phases between BPMs and correctors by comparing the phases at BPMs and correctors at the applied excitation frequency derived from the FFT.

The sign convention in the yellow ring of the new dipole correctors was found to not be consistent with that of regular correctors, which caused some confusion in the earlier days. The dipole sign convention at RHIC is: positive deflection for positive BPM reading; e.g. outward or up deflection for both beams, which has the consequence that the orientation of the fields of the dipoles were opposite in the blue and yellow ring. Once identified this was subsequentially corrected.

Results from these methods are consistent with relative differences on the level of 2%. In the following, we only present one set of ORM measurement for comparison.

ORM FROM MODEL

The closed orbit at an arbitrary position s with a kick θ from a corrector at position s_0 is [5]

$$y(s) = G(s, s_0) * \theta(s_0) \quad (1)$$

where

$$G(s, s_0) = \frac{\sqrt{\beta(s)\beta(s_0)}}{2\sin(\pi \cdot Q)} \cdot \cos(\pi \cdot Q - |\phi(s) - \phi(s_0)|) \quad (2)$$

Based on Eq. 2, the model ORM is calculated with Twiss parameters extracted from online model, OptiCalc.

COMPARISON OF ORM

For comparison, the relative differences between measured ORM and model ORM are shown in Fig. 4 and 5. The fact that most of the relative difference is negative indicate that the real response of most BPMs to correctors in both rings are less than what is predicted by the model.

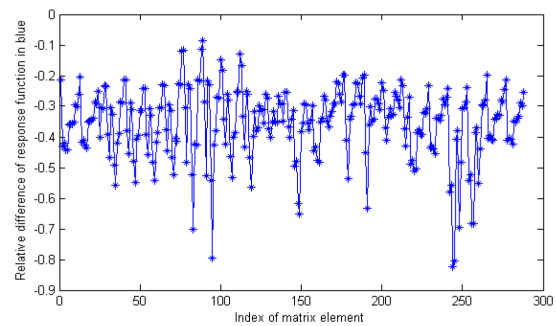

Figure 4: Relative difference of measured ORM and model ORM in blue ring for store condition.

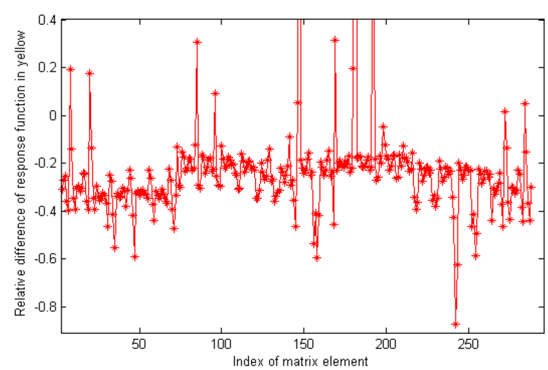

Figure 5: Relative difference of measured ORM and model ORM in yellow ring for store condition.

APPLICATION OF MEASURED ORM

Inversion of the ORM using SVD algorithm was motivated largely by limitation of available corrector strength. Studies [6] showed keeping 6 of 12 eigenvalues for SVD matrices achieved the best feedback performance while maintaining corrector current within limit($\pm$ 12 A).

The so called 10 Hz oscillation are actually oscillations with frequencies distributed around 10 Hz. To see the effect of ORM calibration, we compared the integrated intensity of the beam spectrum around 10 Hz for two cases: feedback with model matrix and with measured matrix. The comparison of peak intensity is equally effective and showing similar results as in Fig. 6 and 7.

Consistent improvement of beam spectrum was seen on most BPMs in blue ring, however, the result in yellow ring

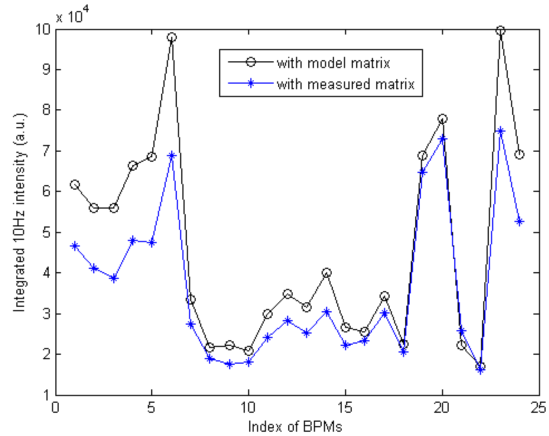

Figure 6: Comparison of the integrated 10 Hz intensity with model ORM and measured ORM in blue ring at store.

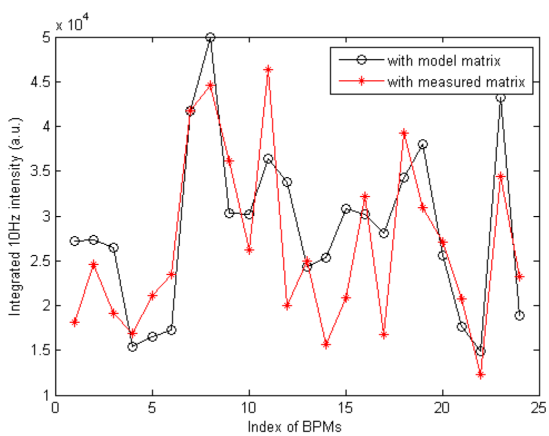

Figure 7: Comparison of the integrated 10 Hz intensity with model ORM and measured ORM in yellow ring at store.

is still puzzling. The intensity at IR6 and 8 are higher because of the larger β-functions of the BPMs due to β^* squeeze.

If normalized by square root of β-function, only IR4 intensity is higher than the others as shown in Fig. 8. We believe this to be related to the fact that liquid Helium feed line is located in that region.

SUMMARY

ORM data were taken in RHIC for both blue and yellow rings for 10 Hz feedback system. The measured and model matrices were compared which revealed measured responses are systematically lower than model prediction on the level of 20% to 30%. The calibrations have been implemented during physics stores. Appreciable improvements were observed in the blue ring without side effects (impact on beam loss, luminosity...).

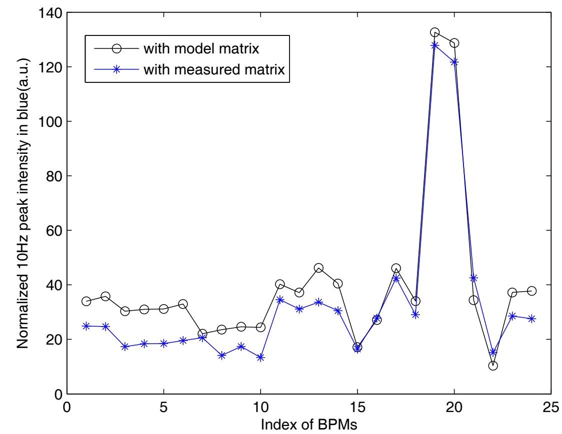

Figure 8: Integrated 10 Hz intensity along blue ring being normalized by square of β-functions at corresponding BPMs.

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